THE CHALLENGE OF USING SOFT COMPUTING FOR DECISION SUPPORT DURING LABOUR

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Abstract-**This paper presents the development of a Decision Support System for managing the labour based on the Soft Computing technique of Fuzzy Cognitive Maps. During labour, obstetricians manage and take decisions on the fetus delivery and the procedure of the labour, monitoring continuously a visual recording of the fetus heart signal and uterine contractions and they also take under consideration other physiological medical measurements and factors. Obstetricians utilize their experience and they decide either to proceed to a natural labour or to a Caesarean section. The developing system for managing labour delivery will combine evaluation of cardiotocographic signal with other physiological data in order to create an advanced Decision Support System.**
***Keywords*: Soft Computing, Fuzzy Cognitive Maps Modeling, Decision Support Systems, Neural Networks.**

I. INTRODUCTION

During labour, a difficult and critical problem often faced by obstetricians is how to accurately discriminate between a fetus that is perfectly normal and is coping well with the stresses of labour, and one which is not coping well with labour and has become distressed. A worldwide-accepted method for monitoring fetal status is cardiotocogram (CTG). CTG is the continuous display of Fetal Heard Rate (FHR) pattern together with the contraction of the womb (uterine activity). Moreover, they take under consideration other important physiological factors for the labour, such as fetus blood sampling, medical history of the specific patient (obstetric history, risk factors etc) and labour events (administration of drugs, epidural insertion etc).

Obstetricians evaluate cardiotocogram and others factors and decide if they will proceed to Caesarean section or natural labour. It must be mentioned that considerable expertise is required to interpret the changes of fetal's heart signal seen on the recording and combine this with further information and then obstetricians decide either to continue or intervene. Difficulties in cardiotocogram interpretation lead to unnecessary caesarean section as well as a failure to intervene when necessary. In the first case there is great financial cost and it is quite hazardous for mother's condition, on the other hand the second case is extremely dangerous for baby's mental health (birth asphyxia) and thus there is social and financial cost.

All these make apparent the importance of an intelligent system that will assist obstetrician to take the right decision. This system will evaluate cardiotocogram and other qualitative and quantitative measurements and will suggest the best solution to the obstetrician. First of all a software tool is developed to acquire and processing data and then there is the DSS system which is consisted of a Neural Network and a Fuzzy Cognitive Map. The Neural Network is used to interpret and classify the cardiotocogram and its outputs pass to the Fuzzy Cognitive Map along with other inputs and Fuzzy Cognitive Map suggest the most appropriate action.

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II. FUZZY COGNITIVE MAPS

Fuzzy Cognitive Maps (FCMs) belong to the soft computing approaches that are used to model and describe the behaviour of dynamical systems [1]. They aim to solve real world decision-making problems, modeling and control problems [2][3][4]. They are neuro-fuzzy systems and they have the ability to incorporate human knowledge and to adapt their knowledge base via new optimization techniques. Thus there are likely to play an increasingly important role in the conception and design of hybrid intelligent systems for discipline scientific applications [5][6].

Fuzzy Cognitive Map is a signed fuzzy graph with feedback, consisting of nodes and weighted interconnections. Nodes of the FCM stand for concepts that are used to describe main behavioural characteristics of the system. Signed and weighted arcs represent the causal relationships that exist among concepts. There are no limitations or directions on the connections among concepts, a concept can be connected with all the other concepts; so cycles of cause and effect, direct and indirect feedback can be included in the FCM structure. Accepting this kind of interconnections among concepts, systems of any dynamic can be modeled with a FCM. Concepts reflect attributes, characteristics, qualities, and senses of the system. Interconnections among concepts of FCM signify the cause and effect relationship that a concept has on the others. These weighted interconnections represent the direction and degree with which concepts influence the value of the interconnected concepts. FCM is consisted of N concepts that are connected. Each connection is characterized by a correlation weight that describes influence of one concept on the other. Fuzzy Cognitive Map is an expert network, which is built by experts, using an interactive procedure of knowledge acquisition. Experts design a fuzzy graph structure of the system, consisting of concepts-nodes that represent the key principles - functions of the system operation and behavior. Then, they determine the structure and the interconnections of the network using fuzzy

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conditional statements. The interrelationships among these concepts – main characteristics of the system - are depicted as fuzzy weighted arcs between concepts [7]. Experts use IF-THEN rules in order to describe the relationship among concepts, and then all these rules are combined and Fuzzy Cognitive Map is developed [8].

For complex systems, it is quite impossible to develop a detailed model of the systems. On the other hand human experts have knowledge and experience on the existing causal relationships among the involved different factors, states, and variables. Experts conceptualize the behavior and mental situation of the problem or system and they describe the complex human system based on their intuitive and qualitative perspective of existing causal relations. Fuzzy Cognitive Map (FCM) is a symbolic representation for the description and modeling of systems, describing different aspects in the behavior of the systems in terms of concepts and interactions among concepts that show the dynamics and interrelationships of a system.

III. THE VALUE OF CTG DURING THE ANTEPARTUM PERIOD

Recording of Fetal Heard Rate (FHR) and uterine activity (UA) after the 36th week of gestation and every week is 'routinely' applied to each pregnant woman. The cardiotocograph (CTG) is an easily performed test, which lasts from 10 to 20 minutes, takes place in the outpatient clinic and gives valuable information about the fetal condition before labour.

According to Federation of Gynecologists and Obstetricians (FIGO) a CTG can be interpreted as normal, suspicious and pathological but the common classification for the obstetricians remains reactive and no reactive. Because of the low cost and the ease with which information about the fetal condition can be obtained, CTG monitoring every week has become universal.

A. Cardiotocographic signal Characteristics

A software tool is developed for the acquisition preprocessing and processing of the cardiotocographic data. The output of the tool will be either qualitative information on the classification of CTG and /or input to the Neural Network that will interpret the CTG.

The continuous recording of the fetal heart rate is based on the ultrasound signal. The autocorrelation of this signal can improve the FHR trace, but the autocorrelated signal has spiky "artifacts" (abrupt changes by more than 35 bpm) and also sometimes the rate is halved or doubled. In order to improve the signal whenever a difference between adjacent beats is higher than 25 bpm, simple linear interpolation is implemented. An interpolating algorithm is used between the first of those two samples of the signal and the first new “valid” sample of the FHR signal.

Moreover the same interpolating algorithm is used for the case of missing beats. The proportion of the signal that is replaced by linear interpolated values and the proportion of the signal with very low quality are used as a measure for the acceptance or not of the trace as valid to be submitted for further processing.

The Uterine Activity signal also needs to be processed for the removal of the high frequency components using a low pass filter. The uterine resting tone has to be estimated and it is estimated as the mode of the low-pass filtered UA signal. Then the Uterine Contractions are calculated as an increase of the UA signal 10 (relative) units above the resting tone and lasting more than 40 secs [9]

The processing of CTG includes extracting the characteristics and other useful information from the data, the baseline and the periods of accelerative and decelerative patterns can be calculated. The quantitative measurements of the cardiotocographic features are primarily based on FIGO guidelines [10].

The baseline is "the mean level of the fetal heart rate when this is stable, and accelerations and decelerations being absent". A consequent and reproducible estimation of baseline is an essential prerequisite for any objective description of fetal heart rate recordings. Nevertheless, baseline of FHR has a hypothetical nature, because there is no experimental way to verify whether or not the estimation of baseline is valid [11].

The following algorithm is proposed and implemented to calculate baseline: the data after the removal of the artifacts and the filling of the missing beats are passed through a low pass fourth order zero-phase (two pass) Butterworth filter with a cut off frequency of 0.008Hz (sampling frequency 4 Hz). By heavy low passing the FHR data a rough estimation of the so-called "running" baseline is calculated. The data are also passed through a low pass fourth order zero-phase (two pass) Butterworth filter but with a much higher cut off frequency than that of the first stage (of 0.4Hz.). A rough approximation of the original signal is created after removing the high frequency components but leaving the accelerations and decelerations that give rise to low frequency components and thus can easily pass the filter. Subsequently the product of the second stage is subtracted from the output of the first stage and if the absolute difference is above 5 beats per minute the original beats are considered as part of a deceleration or acceleration and that particular segment is replaced by linear interpolated values. Finally the data (after the filtering the "pruning" and the linear interpolation) are passed through a low pass fourth order zero-phase (two pass) Butterworth filter but with a cut off frequency of 0.004Hz and their mode is considered to be the baseline of the trace.

Accelerations are determined as increases from FHR baseline greater than 15 beats per minute and lasting more than 15s. This comparison is made between the calculated Baseline and the signal after passing through the filter with the cutoff frequency at 0.4 Hz. The number of accelerations and "mild" accelerations [12] is computed and their temporal positions also marked on the display of the tool.

Decelerations are determined as decrease from FHR baseline greater than 15 beats per minute lasting at least 15s. The system classifies the decelerations as early, late or variable in accordance to their position considering the peak of the more approach uterine contraction.

Long-term variability is calculated as the difference between the highest and the lowest FHR during one-minute using an algorithm based on amplitude of variability. The Long Term Variability is considered reduced/absent if it is less than 5 beats per minute, normal if it is in the range between 5 and 25 beats per minute and increase if exceeds 25 beats per minute.

B. Classification of CTG

The criteria for the classification of the fetal heart rate patterns were however mainly based upon empiricism [13]. The proposed tool classifies the tracings as normal, suspicious and pathological utilizing a number of fixed criteria in accordance to FIGO's guidelines for the antepartum period. These criteria are summarized in Table 1.

Table 1. Scoring system for classification of CTG

	Normal	Suspicious	Pathological
Baseline (beats/min)	110-150	100-110 or 150-170	<100 or >170
Variability (beats/min)	5-25	5-10>40 min or >25	<5 >40 min or sinusoidal
Accelerations (n/10 mins)	2+	absent >40 min	Absent
Decelerations	absent	occasional and small	any recurrent or large, long or late

At this point, it must be mentioned that the precise calculation of the CTG quantities and so the extraction of CTG features and characteristics is very tough task requiring more clinical experience and expertise and a Neural Network classifier could have better results [14].

IV. Neural Networks for Feature Extraction from Cardiotocogram

Two major problems arise at the interpretation of the CTG; above all even the most experienced obstetricians do not agree to each other when a CTG is normal, suspicious or pathological. Furthermore, a normal CTG does not guarantee the well being of the fetus and on the other hand a CTG with late decelerations may lead the doctor to perform a Ceasarian section, which is many times unnecessary. Despite all these problems in CTG interpretation, CTG remains the most basic tool that supports clinical decision. The accurate and consistent interpretation of cardiotocogram during labour is an important problem for obstetricians. The interpretation of cardiotocograms can determine and describe important factors during labour such as fetus distress, asphyxia and others.

Neural Networks have the ability to recognize nonlinear patterns and they can used to recognize CTG key features and interpret CTG. The use of numerical algorithms to preprocess the raw data and then they applied a Backpropagation Neural Network for complete classification of CTG have been proposed and the use of the Generalized Regression Neural Network to classify the FHR and predict artifacts and decelerations in the CTG signal and methods for training NN to recognize CTG characteristics were developed. Neural Networks can be trained and learn to detect any key feature of CTG such as acceleration, contractions and etc. [15][16].

It is proposed the use of a Neural Network classifier of CTG that will give as outputs the features of FHR. This NN is emulating the experienced obstetrician who recognizes patterns of FHR on the printer's paper and infers on fetal' s condition from CTG features. Neural Network have inputs from the CTG signal the important features of FHR that are are: FHR variability, early deceleration, late deceleration, accelerations and variable deceleration; and then the output of NN is the characterization of CTG as normal, pathological or suspicious. Supervised learning techniques are used in training the Back propagation Neural Network.

V. Fuzzy Cognitive Map Model of the System Usage of CTG During Labour

Despite the many controversies cardiotocography remains the basis for the clinical assessment of fetal condition during labour. While in high risk pregnancies during the antepartum period monitoring of the FHR rhythm is usually combined with other biophysical information, during labour CTG is used as a single parameter of the fetal condition. It is clear the need for the establishment of an expert system that will automatically analyze the CTG and will propose an appropriate solution to the obstetrician. The algorithm by which the obstetrician makes a decision for a normal delivery or a caesarean section is used to design the Fuzzy Cognitive Map model.

The parameters, which are evaluated by the physician, are described below:

A. Bishop score

Bishop score describes the conditions of the woman to deliver naturally. Having a cervical dilatation less than 3 and a pathological CTG means that the physician does not expect this woman to have a normal labor

B. Uterine contractions

Uterine contractions are the second parameter that is taking into consideration. Evaluating their intensity and frequency and because of the wide spread of oxytocine nowadays if they are automatically or induced. The decelerations of the CTG are evaluated according to the uterine contractions and of course the pharmaceutical dose of oxytocine can be adjusted or even stopped it if there are prolonged, sever or repetitive decelerations as a first measure before deciding to perform a caesarean section

C. Presence of meconium

The presence of meconium is a condition of stress to the fetal and leads many times to abnormal CTG

D. Duration of labour

Duration of labour is also a critical point, as is known that labour is a continuous state of stress to the fetus. Adjusting the pharmaceutical dose of oxytocine when contractions of the uterine are not satisfactory or there is no improvement in the Bishop score taking into account that the FHR monitoring is normal can accelerate duration of the labour.

E. Oxytocine

The quantity of the oxytocine, which has been given to the pregnant. In case of a suspicious CTG, the oxytocine have to be reduced.

This is the critical point where the clinician needs an expert system to help him to distinguish between physiological stress and pathological distress and to decide whether he can wait or a normal labour or perform immediately a Ceasearan section.

Experienced obstetricians take into consideration all these factors during labour. They have exploited their clinical experience in order to develop the Fuzzy Cognitive Map consisted of 9 concepts that are presented at Table2 and depicted on fig. 1. Their knowledge on managing the labour was utilized and representing in the concepts of the FCM and the weighted interconnections among them.

The relationships among concepts are represented by the corresponding weights. So the influence from concept C_i towards concept C_j is presented by the weight W_{ij}. Experienced obstetricians have estimated the degree of influence from one concept to another using linguistic variables that are transformed into the interval [-1,1] where weights of Fuzzy Cognitive Map take values. The fuzzy values of interconnections suggested from different experts can be integrated and then transformed in numerical weights with methods presented [8].

When FCM runs, at each step values of concepts are calculated according to the influence from interconnected concepts. Some concepts can have external input such as the concept C_3 (FHR) that receives its input from the Neural Network, which evaluates the signal of FHR. The interactions among concepts will change values of concepts. New values on some concepts may mean some action from the obstetrician as an example new value for oxytocine requires pharmaceutical action to the woman. When system reaches the steady state, value of concept for Natural delivery and value of concept for Ceasarian section have to be exclusive and only one suggestion will be the outcome of the system.

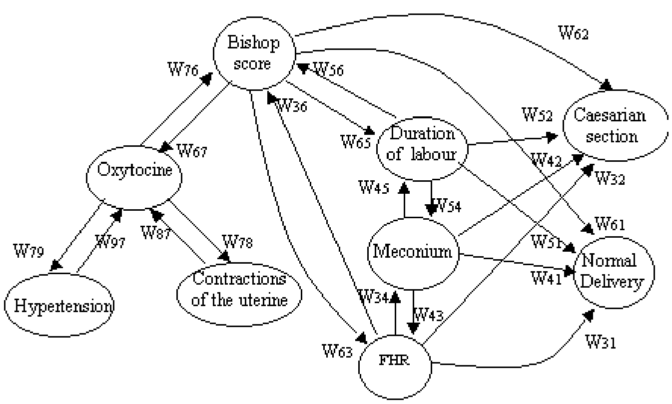

Fig. 1. Fuzzy Cognitive Map for Decision Support

Table 2 Description of concepts

Concept 1	Decision for Normal Delivery
Concept 2	Decision for Ceasarian section
Concept 3	FetusHeard Rate (FHR)
Concept 4	Presence of Meconium
Concept 5	Time duration of labour
Concept 6	Bishop score
Concept 7	Oxytocine
Concept 8	Contrctions of the uterine
Concept 9	Hypertension

VI. CHALLENGES AND CONCLUSIONS

The development of an integrated system that will support obstetricians on their decisions during labour is envisioned. Better understanding of FHR patterns and the use of Neural Networks can lead to new improved methodologies for extracting important features from cardiotocogram. Within this framework novel methods for digital processing of CTG that analyze trends of signal, reconstruct lost CTG traces, perform objective FHR analysis and have advanced potential in classifying and interpreting FHR patterns. Moreover our research work is focusing on utilizing Fuzzy Cognitive Map as a model for decision support during labour. Characteristics of Fuzzy Cognitive Maps and their development methodology, which is based on human experience, make them suitable for application in this kind of decision-making problem.

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